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Self-configuration Concept to Solve Physical Cell ID Conflict for SON LTE-based Femtocell Environment

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***Abstract*— Self Organizing Network (SON) which includes: Self-configuration, Self-organization and Self-healing functions are the most important concepts for self-managing heterogeneous network. However, the concept of self-configuration can be used to solve various challenges in the femtocell deployment phase and also in the PCIs confusion and collision problems. However, the proposed solutions for interference mitigation are not satisfying and need further improvement. Two main reasons identified for this unsatisfactory, firstly the small number of femtocells used in the simulation scenario which can lead to high failure probability if applied under real enterprise environment , secondly; the provided solutions discussed only part of the problem ,i.e. either in co-tier interference or cross-tier interference but not both. Thus the need arises for stable solution which can resolve the interference problem for both inter and intra scenarios. In addition among the tree types of approaches used to solve collision and confusion problems the Nokia Siemens approach was the best.**

***Index Terms*— Self-configuration, cross-tire and co-tier interference, SON, LTE-femtocell, interference.**

I. Introduction

In mobile networks, approximately 2/3 and more than 70% of calls and data service respectively , have been done indoor[1], hence it is important for mobile network providers to provide a good indoor signal for voice , video and data. Yet, the result of a survey showed that 45% of houses resident and 30 % of indoor businesses suffered from poor indoor coverage signal and data service quality[1].These dissatisfactions will increase in the case of fourth generation broadband mobile, such as LTE, due to the high frequency that used in such technology where that leads to higher attenuation losses occurs during walls penetration for indoor users. From this point onward the need of new robust solution is essential for the new demand. Femtocell or Home evolved Network Base station (HeNB) suit the choice to overcome such problems .However due to the femtocells ability of turning on/off and changing their position, the classical network design schemes for configuring and optimizing femtocell networks are not feasible. Furthermore, most of femtocells users have no technical experience background, hence it is essential for the femtocell units to able to operate autonomously with the capability of self -integration with the radio networks that already existed to avoid any undesirable effects on the communication systems created by the new femtocell. This paper provides an overview on one of the most essential roles of SON components which is self-configuration, also provides

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some of proposed works that adapted self-configuration concept to solve co-tier and cross-tier femtocell interference problem.

A. Physical Cell Identity(PCI)

PCI is used by User Equipment (UE) to identify a specific femtocell. In addition ,PCI is one of the most important parameters in the configuration process in SON .Moreover, the number of unique PCIs that been supported in macrocell is 504 due to the needs of compatibility with legacy base station[7].For that, reuse PCIs is normal ,for example consider that our task is deploying a LTE network in an urban area that needs 1500 cells ,where each of the 1500 cells have to have their own cell ID ,however since there are only 504 physical cell IDs (PCI) ,then reusing the PCIs is inevitable ,where in this case, each PCI must be used for three times .Moreover ,the three cells that share the same PCI must not be geographically closed to each other ,by not doing so ,that may bring along with it an interference problems.

II. SELF-CONFIGURATION PROCESS

Self-configuration can be describe as a process occurs when a new nodes are deployed, where these nodes are automatically configured by the autonomous installation procedure to configure all the needed primary configuration for the operation of the system [2].The process of self-configuration is triggered in pre-operation state ,which is the state where the femtocell power turned on and has connectivity to the LTE's system core via a gateway[3]. Figure 1 shows the four phases of the Self-configuration process[4].In other words, the femtocell connected to the subsystem of self-configuration to configure the initial femtocell's parameters, this process undergoes three steps: basic step, initial radio configuration and self-optimization[5].With the first step, an IP address assigned to the new femtocell, at the same time configuring a gateway to connect the femtocell with the LTE core via security get way. For the second step , femtocell starts setting its parameters , these parameters are list of neighbors and assigned unique Physical Cell Identity (PCIs) to supply mobility management and also to avert the effect of interference with neighbor adjacent cells. Moreover, one of the Self-configuration's roles is allocating the frequency intelligently among the neighboring femtocells [6].

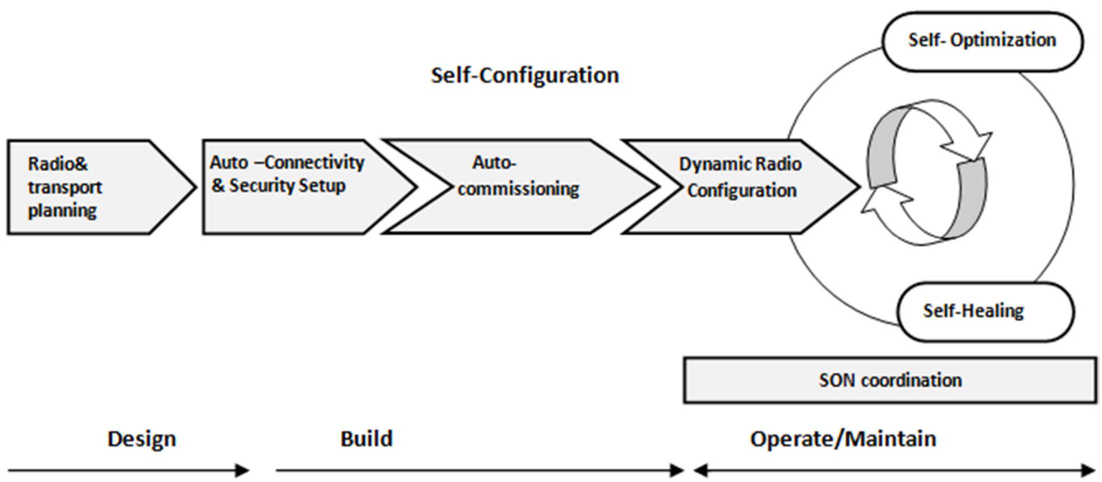

Figure 1. Self-Configuration stages within SON process phases [20]

A. Self-configuration Roles and Stricture

When a new femtocell is being deployed, during this process (deployment) a unique PCI will be selected. However, the reuse of PCIs by various femtocells is inevitable due to the anticipation of high number of femtocells going to be deployed in the near foreseen future, though ,that will lead to cross-tier PCI confusion or collision problem or both .One of PCI's assigning challenges occur regarding the configuration mechanism, which has been used in the current network deployment namely "static planning" [8], besides the disadvantage of being expensive , such mechanism have the limitation of shortage in scale in the case of large number of femtocells. The 3GPP SON's specifications [7] have stated that the used algorithm in any automated PCI's selection have to fulfill the two following requirements in any deployment mechanism [5]:

a) collision-free: a PCI should be unique in the area that the cell cover.
b) confusion-free: a cell should not have neighbor cells with identical PCIs.
Figure 2 depicts PCI collision and confusion where UE represent User equipments. For figure 2-a, looking to the cell B, if the PCI is equal to 500, a collision between Cell A and B will occurs because Cell A and B share the same PCI number (500). Now for figure 2-b, confusion will occur if New Cell D is chosen to have PCI equal to 500 where that will lead to confusion of Cells B and C with A. Consequently a handover from Cell B to the new Cell D will fail. One significant reason for the need of self-configuration in femtocell is the femtocell's location , which can be changed and also able to switch on/off at any time by the user. Therefore it is essential for femtocells to configure their Physical Cell Identity (PCI) autonomously during the procedure of booting to mitigate and reduce the confusion or collision with other femtocells or macrocells. Two different mechanisms are used to achieve the target of autonomously configuring femtocells [7]; a) via the backhaul during the booting process, where the operator set a PCI to the femtocell and b) by using the sensing technique , where the femtocell will be able to collects information about the PCIs neighborhood to choose randomly the available PCI. However, due to the anticipated upcoming increase in the number of femtocell (thousands) that will be deployed within a coverage of few macrocells in the foreseen future , reuse of the PCIs in several regions will be inevitable, which in fact is not an
easy task. The final step in the self-configuration process are occur after the successful femtocell registration, next a check for software update (in case if the femtocell doesn't have the latest version), after that , the step of radio interface parameters configuration will take place.

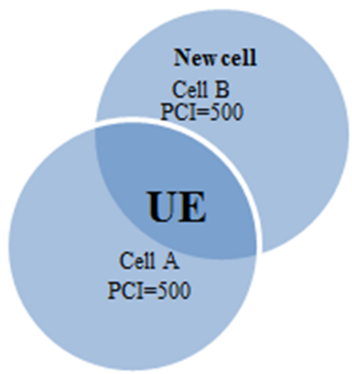

Figure 2. (a) Confusion

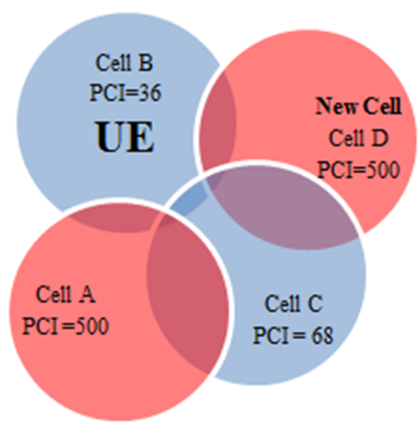

Figure 2. (b) Collision

Figure 2. Illustration of collision and confusion in PCI assignment

III. INFORMATION AND PAPRAMATERS NEED BY FEMTOCELL

There are two types of information that femtocell and its network must have to run [9]:

a) Basic information for femtocell configuration. The basic information that necessary to configure any femtocell are the RF channel information i.e. the frequencies for the uplink and downlink. b) Information needed to configure Femtocell Network. The necessary information to configure Femtocell Network ,are as follows:
i) service information and area code ii) list of neighbors iii) PCI iv) RF parameters including pilot, maximum RF power, etc. The aforementioned information ,generally, supplied by the backhaul channel from the Operation Support Subsystem (OSS) .However, in case of OSS failed to provide these information ,femtocell still have the ability to detect the conditions to configure itself accordingly, yet it is preferable to have the information from OSS itself to insure that femtocell configuration will be done according to the network requirements.

IV. Algorithms And Approaches That Used To Solve Pci‟S Assignment And Conflict Problems

Using Self-Configuration concept to solve challenges in LTE-Femtocell , where concept of self-configuration can be used to tackle different problem types in femtocell ,such as PCI assignment and femtocell interference . Having femtocell with collision and confusion free, needs a robust mechanisms. Various algorithms have been proposed to assign PCI in a such way that reduce the probability of collision and confusion to small as possible ,at the same time reassigning affected PCIs .There are three main approaches used frequently to tickle PCI assignment challenges namely the LTE standard approach, graph coloring approach, the Nokia Siemens (NS) approach[14]. The possible scenarios that any approach may faced are i) static scenario, where all femtocell or eNBs are deployed and switched on once, ii) growing scenario, where femtocells or eNBs are added to the network one by one at random times and iii) dynamic scenario, where the eNBs deployed randomly [15] .

A. LTE-Standard Approach

To achieve collision- and confusion-free assignments, the LTE-Standard approach is proposed through the released 8 of the 3GPP standard [16] .the 3GPP suggested a PCI selection algorithm with several optional extensions . The algorithm is divided into four main steps, with steps 2-3 being optional. Network operators have the flexibility to implement the optional steps to improve the PCI selection process [2]. • A base station tries to get a valid range of PCls from the OAM. The list of returned PCls depends on the location of the deployment and the operator's planning policies.

• The base station performs neighbor discovery through a broadcasting mechanism to detect the PCls of its neighbor cells, thus avoiding selecting these PCls.

• The X2 interface enables neighbors to exchange a neighbor relation table that contains information about neighbors of neighbors. Therefore, the base station may avoid selecting PCls that result in confusion.

• The base station selects a random PCI from the list of candidate PCls. The base station then sends the selected PCI to the OAM that records this configuration.

B. Graph Coloring Approach

Graph coloring is the problem to color the nodes of a graph in a way that two nodes that are connected with an edge are not as- signed the same color, with a minimal number of colors. To find a minimal number of colors is known to be a NP-Complete problem [17]This minimal number is called the Chromatic Number. For some special types of graphs the Chromatic Number is known in advance. For example bipartite graphs can be colored with only two colors, planar graphs with four colors. For non-trivial graphs the question whether a graph is planar or even bipartite is complex to solve. But it is known from[18] that the Chromatic Number is less or equal to the degree of the graph +1, which can serve as a worst case assumption for the required number of colors. From the definition it is obvious that finding a collision free PCI assignment or a valid coloring for a graph are equivalent problems. To be able to perform the graph coloring, the structure of the cell layout is transformed into a graph with the following steps [9]:

• Cells are depicted as vertices

• Vertices that represent neighboring cells in the network are connected by an edge.

The resulting graph is then colored. The colors are translated to PCIs which are subsequently used for Radio Parameter Configuration. The coloring algorithm used in this approach is the very simple extended greedy algorithm by Welsh and Powell [9], which will find a solution if there is one.

C. Nokia Siemens (NS) Approach

The basic idea of the NS proposed in [14] is to reserve a range of PCIs termed as temporary PCIs, for newly added one or all of the following eNBs ,macrocell or femtocell. To simplified we will assume the added entity is macrocell. So when a new macrocell is switched on, it randomly selects a PCI from the temporary PCIs range and operates with this PCI for a limited duration. During this duration, the new added femtocell tries to detect the femtocell locating in its vicinity. Following that, the new femtocell randomly selects a PCI used neither by its 1-hop nor by its 2-hops neighbors. After that, the new femtocell restarts itself and notifies its neighbors of the new PCI. The developers claim that their mechanism is robust as long as the temporary PCIs are sufficient.

V. CROSS-TIER INTERFERENCE AND CO-TIRE INTERFERENCE

Cross-tier interface is the type of interference that occur among the elements of different network tiers , i.e. between a tier of femtocells and another tier of macrocell. Moreover, due to the two PCI's challenges: allocating without prior planning and the limited number of PCI, the problem of cross-tier confusion has increased. For Co-tire interference PCI assignment problems such as co-tire PCI collision and confusion (conflict) which can be occurred among femtocells belong to the same tier in the network ,

VI. Approaches To Solve Co-Tire And Crosstier Interference Problems

To fulfill the two conditions of collision and confusion free that stated by 3gpp, and to propose a new strategies or algorithms to overcome " static planning" problems , JaeSeung Song et al. focused in their proposed work [6] on one of management problems , which is the self-configuration of femtocell ,where they proposed a model-checking to help formal correctness verification to verify the correctness of the Self-configuration assignments process. This approach have the ability of searching for error in the configuration . starting from partial configuration state snapshot. However their work has done on small sample that did not reflect realistic case where many drawback could appear under larger deployment .

Moreover their algorithm has failed under the concurrent femtocell deployment. Another wok has been done by T. Bandh and G. Carle [9] Proposed a solution for theproblem of PCI interference connected to Co-tier LTE networks ,this solution has developed for the PCI auto-configuration ,this solution namely Coloring-based mathematical method where each PCI assigned to a color that different from its neighbor i.e. different ID based on the theory of graphic coloring. A work by M. Amirijoo et. al. [10] suggested to update the Neighbor-Cell-List (NCL) in the network of LTE single-tier by using UE's measurements to discover PCI interference. The idea is ,if the PCI interference appears ,the UE will send this information to the Core Network (CN) , after that , the Operation Support System (OSS) will request the ID of the femtocells to change their PCIs. However, the above two solutions cannot be considered completed ,due to that the proposed solutions solved only one part of the problem which is Co-tire network and not whole heterogeneous network that include macrocell and femtocell (cross- tier network). 3GPP proposed a solution in its Released 9 [19]. The provided solution namely Cell Global Identity. (CGI) proposed to solve PCI confusion problem Unfortunately the CGI solution wasn't effective enough in such it might cause some drawbacks such as failure inbound-handover. However, some solutions have been provided to overcome this drawback. Ting Wu et.al.in their work [11] proposed a solution to decrease the time needed for PCI planning , the authors proposed an Automation PCI Allocation System (APCIAS) and APCIA method to assign PCI in the cross-tier LTE networks. In their paper the authors used: state information neighbor list information and type information, these information generally represent the cell information that used to assign PCIs and create the PCI resource. Authors proposed an automatic femtocell PCIs allocation by using different access modes to optimize the network to lessen the PCI's allocation operational expenditure (OPEX) The proposed tactic suggests that after specifying the targeted femtocell, Next , detecting the neighbor femtocells to send neighbor's information to center controller where the PCIs assignment can be optimized. Another work done by P.-U. Lee et. al [12] suggested an approach to minimized the period of time that have to be spent on femtocell for selection/reselection process. The two types of PCIs' groups that used in this approach are : reuse-PCI group for femtocell and the other one is for mic--rocell group , which is a unique-PCI-group. In the case, when the user (UE) moves to another microcell service, the network information for this cell will be obtained automatically ,where a certain PCI number will be assigned for both femtocell and macrocell, by using this information it will be easy during the handover process for the UE to recognize the targeted device i.e. a femtocell or macrocell, that leads to minimized the unnecessary time consumed for identification and signaling process with the Core Network .However ,in the above works ,the researchers proposed schemes for cross-tier allocation ,but none of them provide solution to the

problem of cross-tier confusion .A. Diab and Andreas in their paper [14] authors compared the three aforementioned approaches (3gpp standard , Coloring graph and NS approach) extensively where the results showed that NS approach outperforms the other two studied approaches in all studied scenarios since the network converges faster to a steady state and experiences fewer collisions and confusions , consequently the Co-tier and Cross- tier interference problems reduced significantly.

VI. CONCLUSIONS

In this study we proved an overview on both the Self-configuration concept in SON and the proposed techniques that used to reduce or solve the problem of Co-tier and Cross-tier interference in femtocell. However what we can conclude from this study is that most of these solution are whether the sample number of femtocell used in the proposed simulation are small and could fail with larger sample or the provided solutions discussed only one part of the problem i.e. Co-tier interference or Cross-tier interference and not both. Trusted and reliable solution needs to apply complete solution for both problems to insure compatibility between proposed algorithms. In short, more work need to be done to have reliable , collision-free and confusion-free femtocells network. Also, the study shows that best approach used for PCIs assignment is the NS approach ,which outperforms the other two studied approaches in all studied scenarios since the network converges faster to a steady state and experiences fewer collisions and confusions , consequently the Co-tier and Cross- tier interference problems reduced significantly even though the number of samples used in the simulation still not same with anticipated number of femtocell and eNB that could used in large realistic system.

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REFERENCES

[1] David Lopez David L´and Jie Zhang , FEMTOCELLS: TECHNOLOGIES AND DEPLOYMENT Jie Zhang and Guillaume de la Roche pp-225 © 2010 John Wiley & Sons, Ltd

[2] P. Pietzuch : Towards automated verification of autonomous networks: A case study in self-configuration.In: 2010 8th IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), pp. 582–587, Mar. 2010.

[3] C. S. Lixiang Xu1 Xiaoqiang Li1, Chaegwon Lim2, Hong He1: THE METHODS TO IMPLEMENTATE SELF OPTIMISATION IN LTE SYSTEM .In: IEEE, no. 978–1–4244–4817–3/09/$25.00, 2009.

[4] H. S. Seppo Hamalainen and and C. Sartori : LTE SELF- ORGANISING NETWORKS (SON). 2012.

[5] JaeSeung Song Peter Pietzuch: Towards Automated Verification of Autonomous Networks:A Case Study in Self-Configuration.In: 2010 8th IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops) .

[6] F. Mhiri, K. Sethom, and R. Bouallegue : A survey on interference management techniques in femtocell self-organizing networks. In : Journal of Network and Computer Applications, vol. 36, no. 1, pp. 58–65, May 2012.

[7] 3rd Generation Partnership Project :3GPP TS 32.500 Self-Organizing Networks (SON) Concepts and requirements.V10.0.0. no. 6, 2010.

[8] T. Report, "TR 132 816 - V8.0.0 - Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Study on management of Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC) (3GPP TR 32.816 version 8.0.0 Release 8). vol. 0, pp. 0–39, 2009.

[9] T. Bandh and G. Carle :Graph Coloring Based Physical-Cell-ID Assignment for LTE Networks Categories and Subject Descriptors . pp. 116–120, 2009.

[10] M. Amirijoo, P. Frenger, F. Gunnarsson, H. Kallin, J. Moe, and K. Zetterberg . : Neighbor Cell Relation List and Physical Cell Identity Self-Organization in LTE. Wireless Access Networks,Ericsson Research, Ericsson AB, Sweden.

[11] T. Wu, L. Rui, A. Xiong, and S. Guo :An Automation PCI Allocation Method for eNodeB and Home eNodeB Cell .In: 2010 International Conference on Computational Intelligence and Software Engineering, pp. 1–4, Sep. 2010.

[12] P.-U. Lee, J.-K. Jeong, N. Saxena, and J.-T. Shin : Dynamic Reservation Scheme of Physical Cell Identity for 3GPP LTE Femtocell Systems. In: Journal of Information Processing Systems, vol. 5, no. 4, pp. 207–220, Dec. 2009.

[13] Radio –Electronic .com ,"Femtocells Configuration, Organization, and Installation", available online in: http://www.radioelectronics.com,2011.

[14] N. SIMINS, “2Nokia Siemens Networks and Nokia.” Nokia Siemens Networks, Nokia, Nokia Siemens Networks and Nokia. 2008. SON use case: cell Phy ID automated configuration. Technical Report. R3- 080376. 3rd Generation Project Partnership (3GPP), 2008.
[15] A. Diab and A. Mitschele-Thiel :Comparative evaluation of distributed physical cell identity assignment schemes for LTE-advanced systems,” Proceedings of the 7th ACM workshop on Performance monitoring and measurement of heterogeneous wireless and wired networks - PM2HW2N ’12, p. 61, 2012.
[16] 3rd Generation Project Partnership (3GPP). 2009. TS 36.300v8.9.0: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description (release 8). Technical Specification.
[17] R. M. Karp, “Reducibility among combinatorial problems,” in Complexity of Computer Computations, R. E. Miller and J.W. Thatcher, Eds., pp. 85–103. Plenum Press, 1972.
[18] D. J. A.Welsh and M. B. Powell, “An upper bound for the chromatic number of a graph and its application to timetabling problems,” The Computer Journal, vol. 10, no. 1, pp. 85–86, 1967.
[19] T. Specification, “TS 136 331 - V9.2.0 -(3GPP TS 36.331 version 9.2.0 Release 9),” vol. 0, no. 9, 2010.
[20] H. S. Seppo Hamalainen and and C. Sartori : LTE SELF- ORGANISING NETWORKS (SON). pp.82. 2012.